BESIP 2005 SUMMER PROJECT

Segmentation and 3D Volume Analysis of the *In vivo* Human Tongue

Sponsoring Laboratory/Section:

Oral Pharyngeal Function & Imaging Laboratory
Physical Disabilities Branch
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Laboratory Description and Project Area

Using cutting-edge imaging technologies, the Oral Pharyngeal Function and Imaging Laboratory conducts pioneering research on the myoarchitecture and functional biomechanics of the human tongue – an organ vital in everyday living, yet poorly understood due to its anatomical complexity. Our ultimate objective is to develop biologically realistic treatment strategies for patients whose swallowing and speech are compromised due to sensorimotor deficits of the tongue.

The focus of the summer project is to develop and apply computational methods for accurate analysis of task-induced volume changes of the *in vivo* human tongue. The motivation behind our group effort is the desire to carefully evaluate a long-held but untested concept of the human tongue as a muscular hydrostat -- an organ whose myoarchitecture serves as its own hydrostatic skeleton and whose volume is constant. Using advanced Magnetic Resonance (MR) imaging, we have been able to examine differences in tongue volume as a function of lingual contraction tasks. Our analytical tasks are challenging, especially in the areas of tongue segmentation, 3-D reconstruction, and volume estimation, as we strive to achieve maximal accuracy in our analysis. Results of the summer development efforts are likely to be creative and original, as no method to date can automatically and accurately delineate the human tongue from the surrounding tissue/structure.

In this summer internship the student will:

- engage in development activities:
    - work closely with mentors to explore image processing algorithms and develop accurate tongue segmentation and 3-D volume analysis programs using the MATLAB image processing package;
    - learn to segment and visualize the tongue by applying the existing algorithms of an advanced medical image processing software (e.g., MIPAV);
    - perform cross comparisons of tongue volume measurements from different segmentation methods and reconstruction approaches;
- learn about MR imaging and biomedical research:
    - acquire basic knowledge of MRI physics;
    - participate in image data acquisition;
    - gain an understanding, through practical experience, of the interactions among imaging parameters and the optimization of MR scanning protocols;
    - perform other project-related tasks;
- learn about human tongue anatomy and physiology:
    - develop knowledge of human tongue anatomy and an appreciation for its myoarchitecture complexity;
    - gain practical experience from applying such knowledge in hands-on tongue segmentation.

We invite a student with aspirations and basic familiarity with MATLAB to join us in this summer endeavor and grow with us in our pursuit of scientific excellence.

In-Depth Project Description

1. Background

The Oral Pharyngeal Function and Imaging Laboratory of the NIH conducts pioneering research to better understand the functional biomechanics and myoarchitectural intricacies of the human tongue – an organ vital in everyday living, yet poorly understood with respect to structure-function relationships due to its anatomical complexity. Via advanced imaging technologies, our cutting-edge *in vivo* studies of human lingual volumetry, kinematics, kinetics, and hemodynamics aim ultimately at developing biologically realistic treatment strategies for patients whose swallowing and speech are compromised due to sensorimotor deficits of the tongue.

Relevant to this proposal is a project that focuses on MRI-based volumetric changes of the *in vivo* human tongue as a function of lingual contraction tasks, in order to answer the question "Is the human tongue a true muscular hydrostat?" The human tongue has been conceptualized as a muscular hydrostat – an organ whose myoarchitecture serves as its own hydrostatic skeleton. A biomechanical hallmark of a muscular hydrostat is its constant volume. The scientific support for such conceptualization, however, is based solely on animal models. Using advanced MRI techniques, we are addressing this issue in *in vivo* humans. As a result, the project has several important analysis requirements: segmentation of the tongue from the acquired MR images, reconstruction of 3-D data sets from contiguous 2-D images, estimation of tongue volume from the 3-D data set, and comparison of differences in tongue volume as a function of contraction tasks. With these analyses comes the need for advanced algorithms to accurately and even semi-automatically segment the tongue. The development of such algorithms is our current goal.

2. Human Tongue Segmentation

Segmenting the tongue from its surrounding tissue/structure is difficult due to, in most cases, its indistinguishable color from the neighboring tissue and the lack of well-defined boundary. Figure 1a presents an example of a mid-sagittal MR scan of the tongue. In this example, the tongue is in a resting position and touching the palate naturally. Based on color information, we cannot precisely separate tongue from the palate. However, when zoomed in (Figure 1b), we can see that although its color is ‘distorted’, two types of information exist to help an expert identify the tongue region, namely, the shape of the tongue and the local gray level difference.

(a) (b)

Figure 1. Mid-sagittal MR image of the tongue (a) and a zoomed-in version of the same scan (b).

Based on these observations, our first task is to develop a coarse-to-fine adaptive segmentation method that incorporates tongue shape information. This method consists of two steps: elimination of irrelevant image pixels by focusing on the oral cavity; and employment of a clustering algorithm with pre-defined knowledge of the human tongue shape.

Using the downsampling techniques, an image at lower resolution is produced, where the fine details are ignored. In our method, multiple downsampled versions are generated such that the oral cavity is identified recursively with a local search algorithm (e.g., Evolution Strategies and dynamic quad tree). A clustering algorithm (e.g., k-mean clustering) is then implemented. Such a clustering algorithm usually utilizes only the color information, which is insufficient for tongue segmentation. Therefore, we will develop a description of human tongue shape and use it to guide clustering. This description is essentially a 3-D tongue model that provides boundary information from any scanning perspective. Note that this model is a statistical generalization and cannot be applied to fit an MR image set directly due to natural human tongue variations. However, it provides the trend of tongue surface and will potentially boost the accuracy of segmentation.

In addition to participating in the development of new tongue segmentation methods, the summer intern will be guided to explore several existing segmentation methods (e.g., watershed, Fuzzy C mean, etc.) and conduct comparative analysis. Some of these methods are available in the NIH in-house MIPAV (Medical Image Processing, Analysis and Visualization) software.

3. 3-D Volume Reconstruction and Analysis

After the tongue region is properly segmented, the next step is to reconstruct 3-D images and calculate volume of the tongue. Our raw MR images include three tongue postures: rest, static maximum oral hard press, and static maximum oropharyngeal hard press. Each task will have a series of contiguous images, from which a 3-D image will be reconstructed.

Provided that the segmentation results are precise, the accuracy of volume calculation depends on how well the reconstruction is achieved. Since MR scans are compromised results of resolution, slice thickness, etc., missing anatomical details is an unavoidable issue. We will develop methods to recover information from segmented images such that an optimal 3-D image is reconstructed.

Assuming the non-existence of noise or segmentation error, interpolation between image slices is a straightforward way to fill in the missing information, as shown in Figure 2. An important task of the summer intern is to perform guided linear and non-linear interpolations on our existing MRI data sets of *ex vivo* human and calf specimens (acquired at 1-mm and 4-mm slice thickness) and then validate if interpolation actually improves lingual volume calculation. Using previously measured physical volumes of these specimens as references, the summer intern will conduct guided comparisons against image-based post-interpolation volume calculations. Moreover, to address the issue of potential noise or segmentation error in the images, the summer intern will be exposed to image fusion methods and learn to combine 3-D images from multiple planes (e.g., sagittal and axial, or sagittal and coronal) to further optimize 3-D reconstruction of the tongue.

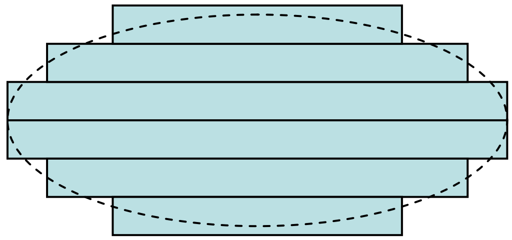

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Figure 2. The dashed ellipse illustrates an interpolation result. Each rectangular box represents the expansion of one slice according to the slice thickness. Conventionally, volume is approximated with the product of the segmented region and the slice thickness, i.e., the region enclosed by boxes. The interpolation removes the staircase on the boundary. Hence, it could improve the accuracy of volume calculation.

4. *Summary*

The primary responsibility of the summer intern will include programming and data analysis. Familiarity with a programming language (e.g., MATLAB) is a prerequisite. The student will also participate in MR data acquisition and other aspects of a scientific project. A first-authored poster is expected as a result of this summer internship program. More specifically, the summer intern will:

1. engage in development activities:
    - work closely with mentors to explore image processing algorithms and develop tongue segmentation and 3-D volume analysis programs using the MATLAB image processing package;
    - learn to segment and visualize the tongue by applying the existing algorithms of an advanced medical image processing software (e.g., MIPAV);
    - perform cross comparisons of tongue volume measurements from different segmentation methods and reconstruction approaches;
2. learn about MR imaging and biomedical research:
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- participate in image data acquisition;
- gain an understanding, through practical experience, of the interactions among imaging parameters and the optimization of MR scanning protocols;
- perform other project-related tasks;

3. learn about human tongue anatomy and physiology:
    - develop knowledge of human tongue anatomy and an appreciation for its myoarchitecture complexity;
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